Improving Working Capacity, Quality While Reducing Energy Consumption During Corn Drying Process

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Abstract

The natural air/low temperature (NA/LT) in-bin drying technology is not adopted in Italy and Europe. The lack of information and successful examples prevent the diffusion and adoption of this technology by farmers. In the last years, an in-bin drying prototype was developed by the National Institute of Agricultural Technology (INTA) in agreement with four companies in order to investigate the applications of this technology in Argentina. The core of the drying system is a model based fan and burner controller. The system was adapted by DISAFA to be used in Italian conditions and installed in two plant of capacity of 70 and 100 t in NW of Italy to dry corn. The goals of this research were: 1) test the reliability of automatic smart drying controller for low-temperature drying, 2) test the performance of a prototype in-bin drying system for drying corn to 14% final MC, 3) evaluate the energy consumption and 4) evaluate grain quality after drying. The results showed that the in-bin drying system was able to dry the grain in about 28 days from 21.5% to 13,7% MC. The individual kernel MC gradient was reduced during drying. The energy consumption was very low compared to traditional mixed flow driers, just about 4.95 L t^{-1} of dried grain. The long drying time was due to the airflow which was just 1.5 $m^3 min^{-1} t^{-1}$ instead of the requested by design of the plant that is of 2 $m^3 min^{-1} t^{-1}$ of grain.

Grain quality was very good with very low stress crack index compared to traditional driers. The very low breakage of kernels during drying with very low air speed imply no detectable dust emission from the plant. These results confirmed the potential of NA/LT in-bin drying systems for drying corn, rice and other special quality grains in NW of Italy.

Keywords: Low temperature drying, corn, energy saving, logistics

1. Introduction

The natural air/low temperature (NA/LT) in-bin drying technology is not adopted in Europe yet. The lack of information and successful examples prevent the diffusion and adoption of this technology by farmers. There is no information about the performance and limitations for local weather and grain conditions. Morey et al. (1979) mentioned that site specific NA/LT drying strategies must be implemented for each location. These strategies consist in different ways to use the fan and the burner along the drying cycle (Dc).

Different strategies and airflow rates were tested by simulation for drying corn in Argentina in a preliminary study (De La Torre, 2010) and on drying rice in North West of Italy (Bartosik et. al, 2007). The strategy with the best performance, in terms of energy consumption, drying time, dry matter loss and over-drying risk, was the one called “smart strategy” (SS). The SS, operated the fan and burner based on the weather conditions (ambient temperature and relative humidity), and a simulation model able to predict the drying process. This strategy can predict the grain moisture content (MC) changes in the different layers and can estimate the remaining drying time. The great advantage of this approach is that using the fan and the burner more or less intensely it keeps the MC of the bottom grain layer between minimum and maximum MC thresholds, reducing the over drying risk.

In the last years, an in-bin drying prototype was developed by the National Institute of Agricultural Technology (INTA). The controller of the fan and burner was programmed with the SS, with the operation parameters optimized based on the results of a previous simulation study (de la Torre, 2010). Each storage bin could be equipped with the system. The fan connected to the bin should guarantee a flow rate of 2 $m^3 min^{-1} t^{-1}$ of grain. A variable, low thermal power burner is also needed to heat up the drying air to dry the grain at the required final moisture. There are sensors to detect the ambient temperature and a controller.

The setup of the plant is showed in Figure 1.

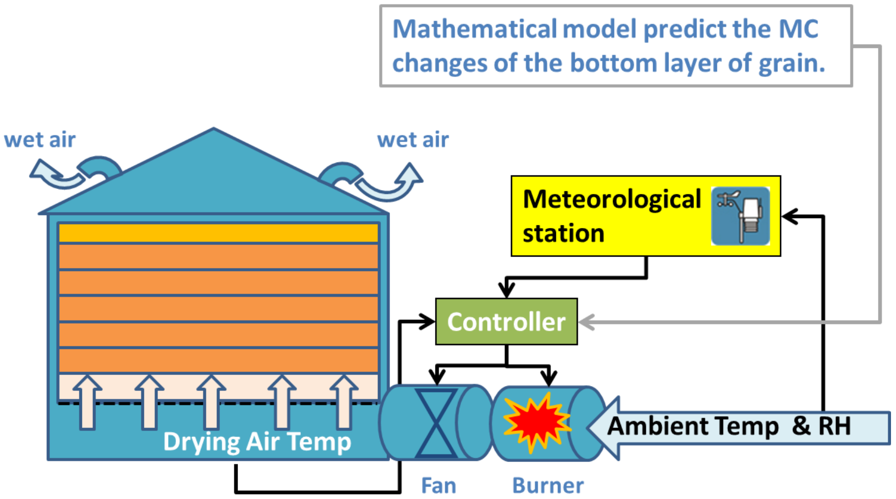

Figure 1- Set up of the low drying temperature plant

The automatic controller turn on and off the burner and the fan following the logic presented in scenarios 1 to 3:

1. Ambient air condition that will overdry the grain in respect to the final moisture content [MC]. Both fan and burner turned off. This happened in North West of Italy for a very limited number of hours during a month.
2. Ambient air condition able to dry the grain in the expected range of MC. Many hours during the month of September are within this range in NW of Italy. Just the fan is running. No burning activity is required.
3. Ambient air that will imply rewetting / drying the grain at higher moisture than expected. This condition will happening some times during the night or during rainy days in NW of Italy. The controller turned on the fan and the burner as well, in order to raise air temperature and lower its relative humidity [RH]. This action will bring inside the bin air which is able to dry the grain at the right MC like in the scenario 2.

The use of the controller make possible to use most of the hours for drying at low temperature in the fall since the drying plant could work also during the hours with high ambient RH. The goals of this research were:

- Test the reliability of automatic smart drying controller for low-temperature drying
- Test the performance of a prototype in-bin drying system for drying corn to 14% final MC
- Evaluate the energy consumption
- Evaluate grain quality after drying

The paper present partial results of trials made on drying corn on North West of Italy region using this technology, in a plant installed in Piedmont Region, NW of Italy.

2. Materials and Methods

A drying bin of 5.63 m diameter and 5.75 m tall, was built with fully perforated floor (positioned at 0.75 m height) and was connected with a fan, at the Cooperativa Maiscoltori Alessandria, in Piedmont region. The fan was chosen by estimating the flow rate with AireAr application that can be found at: http://online.inta.gov.ar:8080/aireAr/login.jsp. The report provided by the software can be seen in Figure 2. The tool provides specific flow rates at different heights of the grain inside the bin, given a grain type, bin size and fan characteristics.

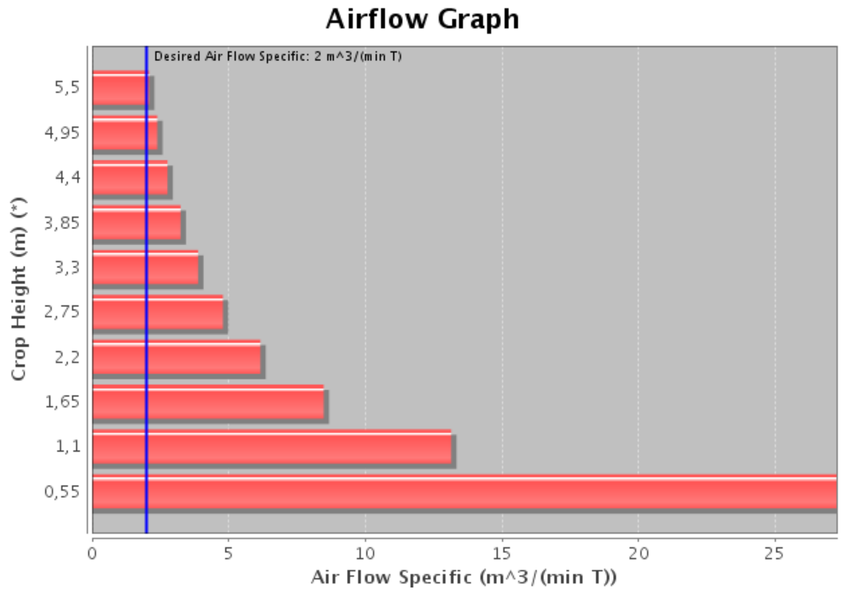

Figure 1- Specific airflow rate calculated for the fan installed at the plant.

The drying system was then equipped with a computer able to run the SS connected to a weather station, with on-time monitoring of weather conditions. The computer had internet connection, which allowed remote control of the trial. A natural gas burner with a maximum power of 115 kW_t with a variable flame control system was connected to the fan. The drying bin was loaded with 105 t of corn grain at 21.5% MC with a setup of final drying process when the grain will be at 14% MC w.b. on average.

The drying process started on September 5, 2015, setting the controller with a target MC of 14%. The ambient relative humidity and temperature, the plenum air relative humidity and temperature were registered during drying. The automatic controller computed the equilibrium moisture content of the ambient and drying air based on the Modified Chung-Pfost equation and the set of parameters values for corn available in the ASAE D 245.5 Standard (ASAE STANDARDS, 1995). The controller also estimates the grain MC change in different layers. All this data was also recorded. Grain samples were taken 11 times during the trial at five layers in the grain mass: 0.5, 1.5, 2.5, 3.5, 4.5 and 5.5 m above the perforated floor. On the samples we measured the MC to see the evolution of the drying front during the drying process. The drying test ended 28 days later, on October, 3, 2015.

3. Results and Discussion

The average airflow, measured on the surface of the grain, was 1.45 $m^3min^{-1}t^{-1}$, with a variation coefficient (VC) of 10%, so it was less than expected (2 $m^3min^{-1}t^{-1}$). This is probably due to the way the fan is connected to the bin that make some resistance to the air and this imply longer drying time that predicted by the controller. During the trial, the fan was running continuously for the whole period, 668 hours (almost 100% of the time) and the burner was not used at all. This means the ambient air was suitable to be used in the drying process without the use of heating.

The MC of the grain follow the pattern in Figure 3. The bulk average MC of the corn was reduced from 21.5 % (initial MC) to 13.7 % MC in 28 days (Figure 3, red line).

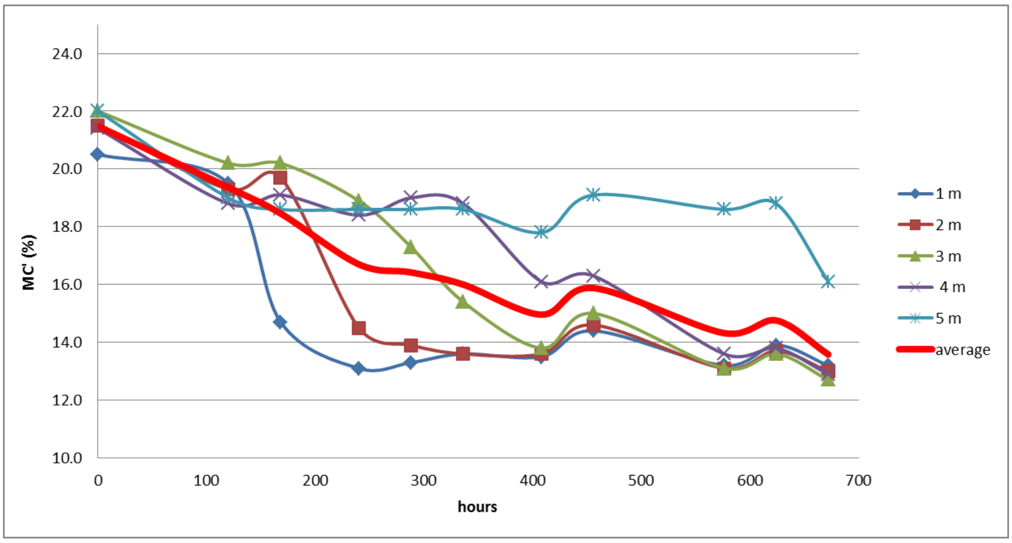

Figure 2 - Trend on MC% evolution inside the bin. 1 m stand for the depth 0-1 m, sampled at 0.5 m, and so on.

We could notice that the grain MC dropped in the first layer (0-1 m) in about 6 days and then it takes other 3-4 days to drop down the MC of the next layers of the grain. The final MC range in the entire grain mass was of 13.7 % while the average MC in the top and bottom layers were 16.3 % and 13.0 %, respectively.

We could also notice that the MC of bottom layer of the grain fluctuates along the target MC (14%). This means it is driven to some extent by environmental condition so we can see these changes in weather have some influence on the bottom layer with a variation of about 1% MC in this layer. However, the uniformity of the MC of the grain when unloaded was very high, with no broken kernels.

The energy consumption was of about 50.5 kWh t^{-1} of dried grain, equivalent to 4.95 L t^{-1} of diesel. This is a very low energy consumption compared to a traditional drying process. Also the very low heating needed, allows for development of electric resistance to provide the heat instead of gas burner. This make safer and easier to manage smoothly the drying temperature.

Trials on dust emission showed no detectable levels of dust. This is due to 1) very low breakage of the grain due to no movement, low stress crack index and low temperature drying and 2) very low air flow rate, about 80 times less than a traditional mixed flow driers.

4. Conclusions

The drying trial made in the fall 2014 with low temperature drying of corn and the smart strategy was very successful. The main results to focus are the following:

- Drying from 21.5 % initial MC to a final average MC of 13,7 % was achieved after 28 days.
- The final MC range was of 13.0 % -13.6%, uniform in all layers except the top one which was still at 16.3 %.
- Low energy consumption, about 50 kWh t^{-1}
- The grain quality was very high, with uniform MC compared to traditional mixed flow driers.

The very low airflow (80 times less than a traditional mixed flow driers) allowed for no detectable dust emission, which is an important positive aspect of this type of drying.

These results confirm the potential of NA/LT in-bin drying systems for on-farm drying corn and other special quality grains and rice in Italy.

Acknowledgements

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References

ASAE STANDARDS, 2003., Moisture Measurement—Unground Grain and Seeds. ASAE 2003. ASAES352.2 FEB03. St. Joseph, Mich.

ASAE STANDARDS, 1995. Moisture Relationship of Plant-based Agricultural Products. ASAE D245.5. 1995, (R2001) St Joseph Mich: ASAE. 3p

Bartosik R., Berruto R., Busato P. and Piccarolo P. (2007). Natural Air/Low Temperature Rice Drying: Feasibility of Application in the North-West of Italy by Means of Simulation. 4th Temperate Rice Conference. S. Bocchi, A. Ferrero, A. Porro, Novara, Italy, pp. 182-183

De la Torre D.A. 2010. in spanish “Study of the demand of energy for drying corn in Argentina”. Magister Scientiae thesis., Universidad Nacional de Mar del Plata. Buenos Aires, Argentina. 99 pp.

Kandala C.V.K., R.G. Leffler, S.O. Nelson, and K.C. Lawrence. 1987. Capacitive sensors for measuring single-kernel moisture content in corn. Trans. of the ASAE. 30:793-797.

Maier D. 2000. In spanish “Drying and conditionning of popcorn” in. “Secado-Libro de Actualización N°1”. Domingo Yanucci. Argentina. 200pp.

Metzger D.D., K. H. Hsu, K. E. Ziegler and C. J. Bern, 1989. Effect of Moisture Content on Popcorn Popping Volume for Oil and Hot-Air Popping. Cereal Chemistry, American Association of Cereal Chemists, Inc. Vol. 66 (3): .247-248.

Morey R. V., Cloud H. A., Gustafson R. J. and Peterson D. W., 1979. Evaluation of the feasibility of solar energy grain drying. Trans. ASAE 22(2): 409-417.